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Fixed feed-in tariff versus premium: A review of the current Spanish system

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ABSTRACT

Since 1998 the Spanish Government established a feed-in system where RES-E generators could choose between two alternatives: fixed feed-in tariff and premium. Nowadays, all RES-E[1] can be sold in the electricity market (getting an additional premium) except for solar photovoltaic. One important novelty established in 2007 is a cap and floor system for facilities under the premium option. The aim of this paper is to analyze and compare these two alternative options, fixed-FIT and premiums, which coexist at the same time in Spain, describe the evolution of both systems and evaluate its performance. The introduction of this support system in Spain led to very good results in terms of RES-E deployment. The main advantage of the premium option is that it is a scheme integrated in the electricity market. One disadvantage is that it can occasionally lead to overcompensation; one way to try to avoid it is to set a cap value. In order to evaluate the performance of this dual support system not only RES-E deployment has been assessed but also the policy stability, the adequacy of RES-E production to the electricity demand pattern and the changes in the investors' behaviour.

Contents

1. Introduction

In recent years the deployment of electricity plants based on renewable energy sources – mainly wind – virtually skyrocketed in Spain. For many authors [1–4], the main explanation for this development is the Spanish support system for RES-E. It consists of two alternative types of support: a fixed feed-in tariff (fixed-FIT) and a premium payment on top of the electricity market price. Both systems are technologically dependent.

This dual support scheme was firstly implemented in 1998 [5]. Since then, several Royal Decrees (RD) have changed some characteristics of the support system, but always maintaining

[1] RES-E: electricity from renewable energy sources.

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both alternatives. One important novelty established in 2007 (RD 661/2007 [6]) is a cap and floor system for facilities under the premium option, which turned the premium into a variable payment. The premium is adjusted each hour depending on the spot market price and the cap and floor values.

The core objective of this paper is to analyze and compare these two alternative options and to evaluate their performance taking into account the cap and floor system introduced in 2007. Regarding the performance of the support system, not only the deployment of RES-E in terms of quantity is important but also criteria like price paid for RES-E generation, policy stability and adequacy of RES-E generation to the electricity demand pattern.

In the literature, the Spanish support system has often been considered a success from the point of view of the RES-E capacity increase [1–4,7]. This success is due to a relative stable regulatory framework for RES-E support and to the design itself of the support system [8]. Other studies at the EU level also took into account the overall cost of the Spanish support system, concluding that Spain achieved the highest growth rates in terms of effectiveness (average values between 1998 and 2005) combined with an adequate profit for investors, resulting in the lowest costs for society per kWh of new electricity generated from RES [9].

Some studies have also compared the premium and the fixed-FIT systems [10–18]. The premium model is offered as an option in the Czech Republic, Slovenia, Estonia, Denmark and Spain [19]. Fixed-FIT models create greater investment security and lead to lower-cost renewable energy deployment than premium models. This is primarily due to the lower risk investment conditions created and the greater predictability of future cash flows [20]. This lower risk investment conditions can encourage the financial participation of smaller and more risk-averse investors, which can help to facilitate RE project financing for non-traditional investors [21].

On the other hand, premium systems could help create a more harmonized electricity market, effectively removing the difference between renewable and conventional electricity [20]. As RE sources increase in market share, the need to further their integration into existing electricity markets is expected to grow [22]. If the premium is a fixed quantity and market prices rise significantly, there is a considerable risk of overcompensation. This can lead to a less efficient market outcome, where prices are higher than necessary to encourage renewable energy market development. This could effectively undermine the gains in market efficiency offered by the premium price model [20].

This suggests that there is likely to be an increasing interest in how the strengths of both approaches can be integrated within one policy framework. One example of this can be found in Spain's current policy framework, which offers generators the option to sell their electricity into the spot market while benefiting from a variable premium payment that increases the predictability of future revenue streams by introducing a cap and floor on the total premium amount. This type of model represents a more market-compatible design that simultaneously provides the necessary protections against both upward and downward price movements, reducing risks both for society and for investors. It is conceivable that models such as this will become more common, particularly as RE sources come to supply a larger share of total electricity demand [20].

A literature review gives some pros and cons of both systems, premium and fixed-FIT [10–18,23] even considering the cap and floor system as one option that retain the best aspects of both systems [4]. In any case, literature about the cap and floor system within the FIT is scarce, probably because this system has only been implemented in Spain (at least in the way that it has been proposed in the Spanish system, which is on an hourly basis) and because it is a relatively new system. To our knowledge, no empirical study has been performed so far based on real market data. In this sense, this paper will provide empirical and novel information, showing data from the performance of the Spanish system during the last years and the effects of the cap and floor system under real market conditions.

Table 1
RES-E objectives for 2010 and 2010 situation.

Technology	Objective 2010	2010
	Power (MW)	
Minihydro (<10 MW)	2400	1997
Wind	20,155	19,548
Photovoltaic	400	3807
Solar thermal	500	532
Biomass	1567	706
Urban waste	350	1261
Total	25,372	27,451

Source: Own elaboration. Data from CNE.

Sections 2 and 3 comprise the current RES-E situation and support system in Spain. Sections 4, 5 and 6 establish a comparison between the fixed-FIT and the premium system, analyzing the performance of each option under different circumstances. Section 7 shows a critical evaluation of the dual system, including design criteria proposals. Section 8 analyzes later the stability of the system's evolution, the adequacy to the electricity demand pattern and the potential changes in the investors' behaviour when the support system is changed from fixed-FIT to premium. Section 9 concludes.

2. Recent development of RES-E in Spain

Spain is a particularly interesting country to perform an empirical study, since renewable energies have expanded significantly in the last years. In 2010 Spain was the fourth country worldwide, after the USA, Germany and China, in terms of wind capacity installed.

The RES-E production in Spain increased from 10 TWh in 1995 to more than 74 TWh in 2009. The major contribution to this development was made by wind energy. On-shore wind energy capacity expanded from 886 MW in 1998 to 16,323 MW in 2008, an increase of nearly 20 times in a decade (see Figs. 1 and 2). In 2009 RES-E contributed to about 27% (not including hydroelectrical power plants bigger than 50 MW) to meet electricity demand in Spain[2].

Table 1 shows the RES-E objectives for 2010 of the “Renewable Energy Plan 2005–2010” of the Spanish Government, as well as the power installed at the end of 2010.

Table 1 points out that in 2010 the objectives for the majority of RES-E sources had been overcome or nearly reached, except for the biomass sector.

3. Description of the current Spanish support system

Since 1998 RES-E generators can choose between two alternatives in Spain:

1. Fixed-FIT: a fix tariff per technology.
2. Premium + market price: a premium per technology on top of the electricity market price.

Nowadays, all the electricity coming from RE technologies can be sold in the electricity spot market (getting an additional premium) or can opt for a fixed-FIT, except for:

- Solar photovoltaic: it can only apply for the fixed-FIT system.

[2] Data from CNE.

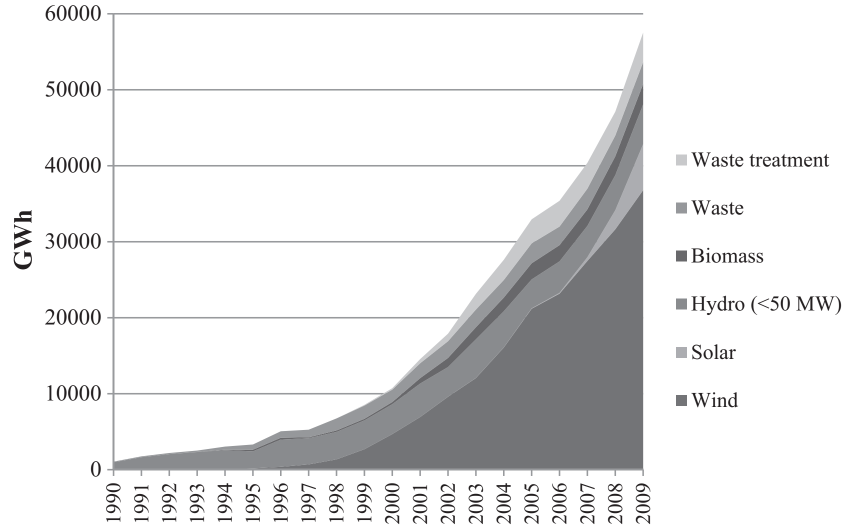

Fig. 1. RES-E evolution in Spain.

Source: Own elaboration. Data from CNE.

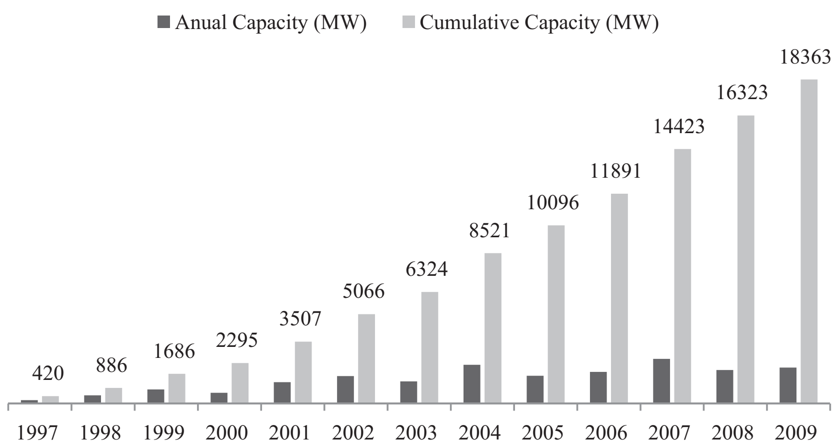

Fig. 2. Evolution of the wind capacity installed in Spain.

Source: Own elaboration. Data from CNE.

- Hydroelectricity with an installed capacity between 10 MW and 50 MW: it can only apply for the premium option[3].

Since 1998, several Royal Decrees (RD 2818/1998 [5], RD 436/2004 [24] and RD 661/2007 [6]) have changed some characteristics of the support system, but always maintaining both alternatives. A description of the evolution of the RES-E support regulation in Spain is not within the aim of this paper since it has already been done elsewhere (see e.g. [8,25]). This paper will focus on the description of the current support system and the comparison of the dual system established in Spain, based on real market data.

The rationale of this dual system was to encourage a gradual participation of RES-E in the market system while keeping a low risk alternative for the risk-averse RES-E investors by ensuring a certain income level, independently of the market evolution [8].

The support system in Spain began with a fixed-FIT per technology. This was perfectly adapted to the RES-E deployment at that time, with RES-E technologies that needed to focus on building a whole new industry and achieving economies of scale. In 1998 the premium system was introduced. However, it was not until 2004 that the regulation allowed RES-E generators to sell their production into the electricity market, what happened in response to the RES-E growth (mainly the exponential growth in wind power). In order to attract investors to this more market integrated option, the premium was theoretically calculated so that RES-E would have a slightly greater income than under the fixed-FIT [4]. RES-E continued to grow, especially wind, reaching high penetration levels. Very soon, new regulations aiming at better integration was needed, leading to the publication of the Royal Decree 661/2007. From the economic perspective, the aim was to improve the stability of the premium option, through the introduction of a cap and floor system. The reason was, on the one hand, to reduce the risk set on RES-E promoters by low market prices and, on the other hand, to curb windfall profits when prices went up. This change was designed to retain the best aspects of feed-in tariffs (income, stability and predictability), while leaving room to play in the market [4]. Fig. 3 shows the evolution of the average yearly electricity prices since the establishment of the Spanish electricity market.

Fig. 3 also shows that during 2005 and 2006 the electricity prices went up quickly, increasing accordingly the incomes of RES-E producers that were under the premium option. This led to overcompensations in some RES-E sectors, making the premium option much more profitable than the fixed-FIT. These unexpected high

[3] The regulation of the special regimen (where RES-E is included) in Spain only takes into consideration facilities up to 50 MW.

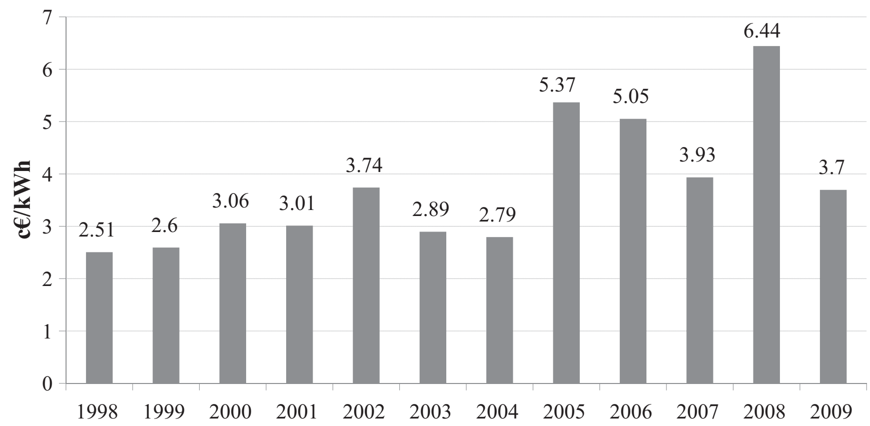

Fig. 3. Electricity prices evolution in Spain.

Source: Own elaboration. Data from OMEL.

revenues under the premium option were the main reason that led to the Governmental proposal of setting a cap value, finally included in the Royal Decree 661/2007 [26].

The cap and floor system turned the premium into variable (the premium was a fixed value per technology before the implementation of the RD 661/2007). The premium is adjusted on an hourly basis, depending on the hourly wholesale electricity prices and the cap and floor values. The floor value is the lowest value that the hourly total support can reach and the cap value is the highest, with one exception: when the electricity market prices are higher than the cap, then the total support will equal the electricity market price (overcoming the cap).

Fig. 4 illustrates the effects of the cap and floor system on the total support level by simulating the revenues for wind energy on the 28 January 2009 in two cases: with and without a cap and floor system implementation. Comparing both sides of the figure when the cap and floor system is implemented, the following conclusions can be obtained:

- During peak hours there is a loss of revenues.
- During base load hours the effect is just the opposite, obtaining higher revenues since the floor value is higher than the expected revenues (market price plus reference-premium).

The value of the average premium in both cases is as follows:

- Without cap and floor: the premium is equal to the reference-premium foreseen for that year; in 2009 this value for wind energy was 3.13 c€/kWh.
- With cap and floor system: on the 28 January 2009, the average premium (average from the hourly premium values) was 3.54 c€/kWh. The maximal premium was 5.41 c€/kWh and the minimum premium was zero. The minimum premium reaches a zero value when the electricity prices reach the cap value, what happened for 1 h during this day.

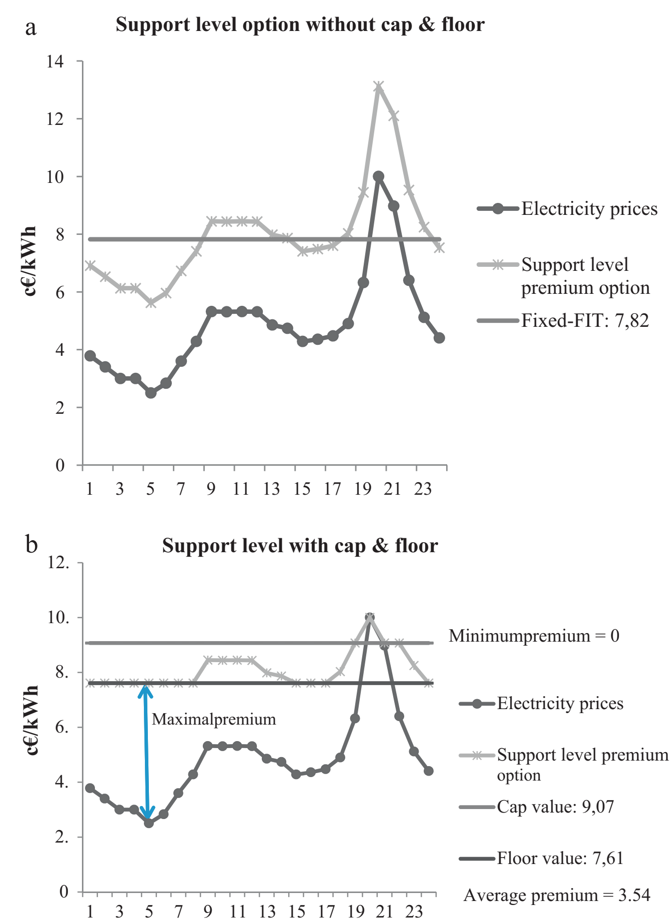

Fig. 4. Support level for wind energy with and without a cap and floor system the 28th of January 2009.

Source: Own elaboration.

The RD 661/2007 regulates the level of support of RES-E[4]. Table 2 shows the RES-E support levels for 2009. Support is guaranteed for the whole lifetime of the facility, but decreases after 15, 20 or 25 years depending on the RES-E technology. Every year, the support levels are updated with the following rule: CPI minus 0.25% until the end of 2012 and CPI minus 0.5% afterwards[5].

All the facilities established after the approval of this Royal Decree can apply for the support established in the Royal Decree until 85% of the objective per technology is reached. Table 3 shows these objectives, which are expressed in terms of power. Once 85%

[4] Except for solar photovoltaic energy that is regulated by a later Royal Decree (anyhow solar photovoltaic is out of the scope of this paper since photovoltaic can only apply for the fixed-FIT scheme and the purpose of this paper is to compare the performance of both, fixed-FIT and premium systems).

[5] From the point of view of the money value, this is a way of two steps degressive tariff.

Table 2
Support level for RES-E in 2009.

Group	Subgroup	Power	Period (years)	Fixed-FIT	Reference-premium	Cap value	Floor value
				€/MWh			
b.1 Solar	b.1.2 Solar thermal		First 25	287.6	271.18	367.25	271.23
b.2 Wind	b.2.1 Wind on shore		First 20	78.18	31.27	90.69	76.1
b.3 Geothermal and marine			First 20	73.56	41.05		
b.4 Minihydro		$P < 10$ MW	First 25	83.28	26.74	90.96	69.61
b.5 Hydro		$10 < P \leq 50$ MW	First 25	–	22.47	85.41	65.34
b.6 Biomass	b.6.1 Energy crops	$P \leq 2$ MW	First 25	169.64	127.89	177.55	164.53
		$P > 2$ MW	First 15	156.51	112.59	161.11	152.36
	b 6.2 Agricultural and garden waste	$P \leq 2$ MW	First 15	134.22	92.46	142.11	129.08
		$P > 2$ MW	years First 15	114.82	70.89	119.47	110.81
	b.6.3 Forest waste	$P \leq 2$ MW	First 15	134.22	92.46	142.11	129.08
		$P > 2$ MW	First 15	126.3	82.38	130.9	122.14
b.7 Biogas and biofuels	b.7.1 Landfill biogas		First 15	85.33	45.13	95.66	79.43
	b.7.2 Biogas from waste	$P \leq 500$ kW	First 15	139.53	10.91	16.37	13.19
		$P > 500$ kW	First 15	103.35	66.47	117.76	101.96
	b.7.3 Dung		First 15	57.23	37.72	88.94	54.45
b.8 Biomass from industrial facilities	b.8.1 Agricultural sector	$P \leq 2$ MW	First 15	134.22	92.46	142.11	129.08
		$P > 2$ MW	First 15	114.82	70.89	119.47	110.81
	b.8.2 Forestry sector	$P \leq 2$ MW	First 15	99.08	57.34	106.98	93.48
		$P > 2$ MW	First 15	69.48	25.56	74.1	65.34
	b.8.3 Black liquor from paper ind.	$P \leq 2$ MW	First 15	99.08	59.99	106.98	93.85
		$P > 2$ MW	First 15	85.41	39.17	96.09	80.07

Source: Royal Decree 661/2007 and Web page of the Ministry of Industry, Tourism and Trade.

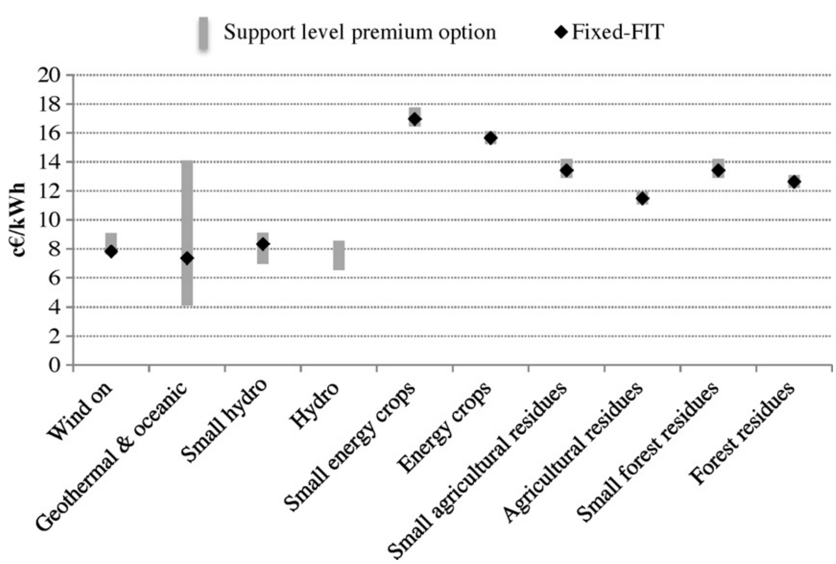

Fig. 5. Total support under the fixed-FIT and the premium options for different RES-E technologies (2009).

Source: Own elaboration.

is reached, the Government can establish a time limit for the inclusion of new facilities under this support scheme.

Fig. 5 shows the total support under the premium option (premium plus electricity price) and under the fixed-FIT for different RES-E technologies for 2009[6]. The total support level under the premium option has been calculated taken into account the values of Table 2 (premium, cap and floor values) and the lowest and the highest electricity prices during 2009. The lowest price was 0.0 c€/kWh (reached in December 2009) and the highest price was 10 c€/kWh (reached in January 2009).

The categories of small hydroelectricity and bio-electricity (groups b.4, b.6, b.7 and b.8) can voluntarily opt for a fixed-FIT with hourly discrimination. In this case, different tariffs for base load and peak hours apply. Table 4 shows how to calculate these tariffs.

Table 3
RES-E's objectives within the RD 661/2007.

RES-E technology	Objective (MW)
Photovoltaic	371
Solar thermal	500
Wind	20,155
Hydroelectricity (<10 MW)	2400
Biomass	1567

Source: RD 661/2007.

[6] The values for solar thermal energy (not shown in the figure) for the premium option range between 371.2 and 272.2 €/MWh; the fixed-FIT is 287.6 €/MWh.

Table 4
Formula to calculate the tariff for peak and base load hours.

Winter		Summer	
Peak	Off-peak	Peak	Off-peak
11–21 h	21–24 and 0–11 h	12–22 h	22–24 and 0–12 h
Fixed-FIT × 1.05	Fixed-FIT × 0.97	Fixed-FIT × 1.05	Fixed-FIT × 0.97

Source: Royal Decree 661/2007.

4. Fixed-FIT versus premium: market and investors

In the last years there has been a preference from the investors' side for the premium system, especially in the wind sector. In 2009, 96% of the wind capacity was under the premium option. In 2003 all the wind capacity opted for the fixed-FIT. In 2004 only 2.5% had moved to the premium system, but in 2006 only 4% remained under the fixed-FIT. In 2004 a new regulatory framework came into force (RD 436/2004 [24]), which encouraged the participation of RES-E generators under the premium option [8]. The main reason for this shift to the premium option has been a higher total support level[7] under this option in the last years; results that can of course not be guaranteed in the long term since they depend on the electricity price development. In any case, since the introduction of the cap and floor system, the risk of the system has been reduced [27].

The high electricity prices in 2005 and 2006 led to windfall profits[8] for almost all RES-E investors that opted for the premium option (especially in the wind area). In December 2005 the wind total support under the premium option reached its maximal value: 16.17 c€/kWh. The average wind total support under the premium option was 9.2 c€/kWh in 2005 and 9.4 c€/kWh in 2006 (the fixed-FIT was 6.6 and 6.9 c€/kWh, respectively).

The exception to this behaviour was the waste treatment sector, where the performance of the premium option has been clearly below than under the fixed-FIT scheme. Therefore, in this sector, the minority that opted for the premium alternative returned to the fixed-FIT option and, nowadays, there is no waste treatment plant under the premium scheme.

The evolution of the total support as well as the generation under the premium and the fixed-FIT options are shown in Figs. 6–9 for different RES-E technologies. These figures have been elaborated using average yearly data.

Figs. 6 and 7 show the general trend until 2009 for most RES-E, which is a continuous increase of the generation under the premium option, in comparison to the fixed-FIT option and, therefore, an increase of the generation share under the premium option. The exception to this behaviour is the waste treatment sector (Fig. 9) and, in the last year, also the biomass sector (Fig. 8), where there has been a slight backward movement to the fixed-FIT.

One interesting question is how big should the increase in the support be to convince investors to move to the premium option. In other words, how much should the support's difference be to compensate the risk associated to go to the market.

Table 5 shows the evolution of the share under the premium option throughout the last years and the corresponding difference (expressed in c€/kWh) between the total support under the premium option and the fixed-FIT, for the wind sector.

From Table 5 it can be observed that, in the wind sector, a difference of about 1 c€/kWh has been enough to foster the movement of more than half of the investors to the premium option. But to convince the risk-averse investors too, the incentive had to be around 2 c€/kWh or even higher.

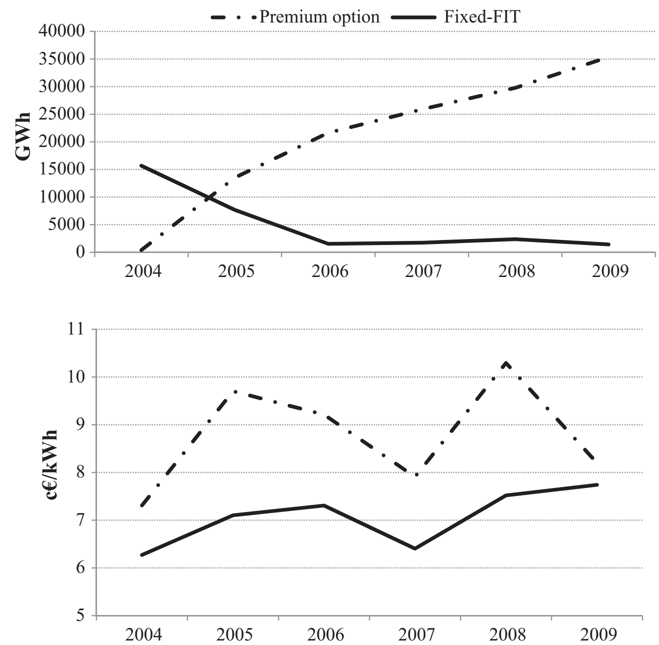

Fig. 6. Generation and total support evolution of wind energy under fixed-FIT and premium options.
Source: Own elaboration. Data from CNE.

Depending on the RES-E sector these values may change. In the minihydro sector a difference of about 1 c€/kWh has also convinced more than half of the investors to move to the premium option. The same happened in the waste energy and biomass sectors.

A general assumption could be that an expectation of 1 c€/kWh difference between premium and fixed-FIT options seems to be enough to move more than half of the investors to the premium option (one could talk here about the risk-seeking investors). To convince the risk-averse investors to change to the premium option, this difference has to be higher and seems to be more

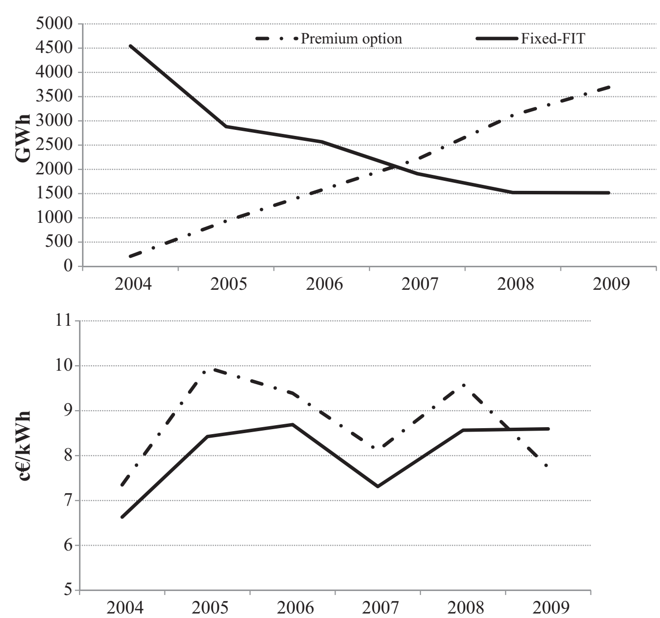

Fig. 7. Generation and total support evolution of minihydro under fixed-FIT and premium options.
Source: Own elaboration. Data from CNE.

[7] Total support level is considered the market price + premium.
[8] Windfall profits are considered those clearly above the fixed-FIT for each RES-E technology (considering that the fixed-FIT will make the investment profitable).

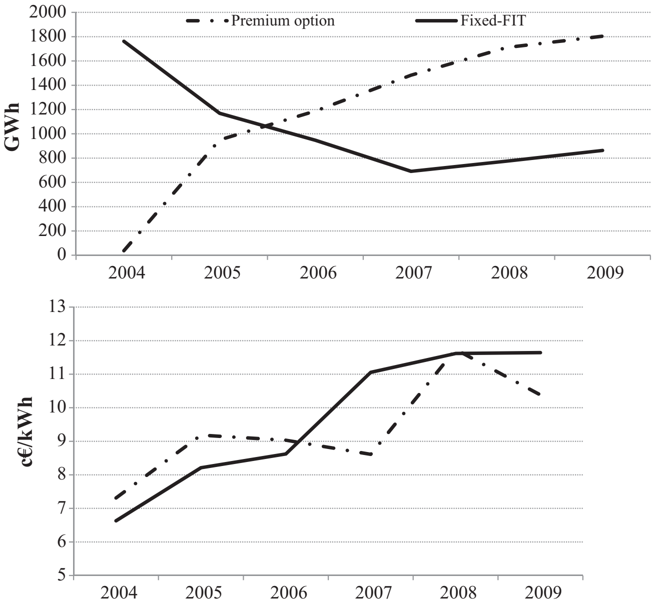

Fig. 8. Generation and total support evolution of biomass energy under fixed-FIT and under premium options.

Source: Own elaboration. Data from CNE.

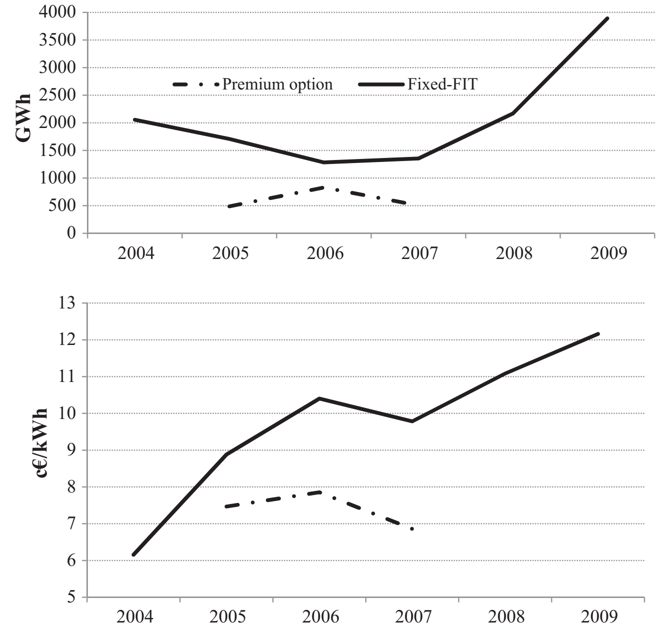

Fig. 9. Generation and total support evolution of waste treatment plants under fixed-FIT and under premium options.

Source: Own elaboration. Data from CNE.

Table 5
Evolution of the premium share and the support differences – wind sector.

Year	Share under premium option	Support difference between premium and fixed-FIT (c€/kWh)
2004	2.5%	1.04
2005	63.8%	2.60
2006	93.5%	1.90
2007	93.8%	1.50
2008	92.7%	2.77
2009	96.2%	0.46

Source: Own elaboration. Data from CNE.

technologically dependant; e.g., in the wind sector a difference of 2.5 c€/kWh seems to be convincing enough while in the sector of waste energy this difference seems to be higher, in the amount of 3 c€/kWh.

These amounts calculated are in line with a number of analyzes that have shown that, on average, premium price policies have been found to be more costly per kWh than fixed-price policies [2,28,29]. This higher cost is reflected in a risk premium that ranges, in Europe, from 1 to 3 c€/kWh [28].

It can also be observed that, once the move to the premium option has taken place, there is a certain reluctance to change again to the fixed-FIT since the same differences are not convincing enough to return to the fixed-FIT. In order to change to the fixed-FIT the performance of the premium system has to be nearly equal (sometimes even worse) than the fixed-FIT. Under similar support levels for both options (differences of 0.1 c€/kWh favourable to the premium alternative), the majority of the investors had just remained under the premium option.

This quick movement to the premium option, despite the higher support under the premium option, can be also explained due to the type of RES-E investors in Spain. Wind energy investors in Spain are mostly consortia of power utilities, regional government and turbine manufacturers, with the role of private individuals insignif-

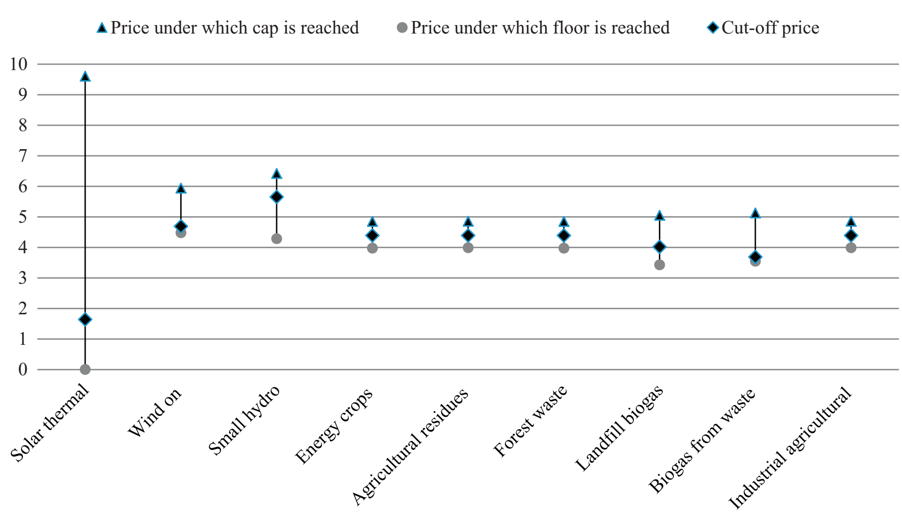

Fig. 10. Cut-off prices and electricity prices reaching cap and floor (2009).

Source: Own elaboration.

icant compared to other countries [30]. This type of consortia is capable of taking more risk than private individuals.

In fact, some authors as Dinica, explained the diffusion of wind energy in Spain by means of the public–private partnerships (PPPs), rather than due to the design of the support system itself. Up to the mid 1990s most investments were based on PPPs, to address the risk perceptions of early investors. Fully private partnerships now dominate investments, though PPPs have not disappeared. The PPP policy led to an investment culture whereby partnership investments dominate. By 2000, 95.7% of the installed wind capacity was owned by partnerships, and only 4.3% by individual companies. Partnerships invest in larger projects, have ambitious investment plans, and these lead to a high diffusion tempo [31].

On the one hand, since the payment levels are predetermined and guaranteed under the fixed-FIT models, they tend to offer greater investment security by allowing more reliable and predictable revenue streams for developers. This greater stability and security is likely to attract a greater diversity of investors (private, corporate, institutional, community-based, cooperative, etc.), due to the more secure contract terms and the greater transparency of the remuneration scheme [2,32]. But, as already stated, the majority of investors in Spain do not respond to this variety of investors' typology and the predominant consortia type found in Spain are big consortia which can deal with the implicit risk associated with the premium system; risk which has been, anyhow, mitigated by the establishment of the cap and floor system.

The greater stability of the revenue streams is likely to be more suitable for emerging technologies, which may not be able to absorb the fluctuations in project revenues as readily as larger and more well-established technologies [20]. Therefore, fixed-FIT seems to be more suitable for these emerging technologies.

On the other hand, for the same reasons mentioned in the above paragraph, fixed-FIT seems to encourage risk-averse investors. In particular, facilities owned by small investors (which represent a minority in Spain); this can be the case of solar photovoltaic energy in buildings and, lately, also of a segment of the biomass sector, which combines both small and big investors in Spain.

The dual system seems, therefore, to be interesting from the point of view of covering the whole range of investors and the whole range of technologies (from the size point of view).

5. Cut-off price and electricity prices reaching cap and floor values

Fig. 10 shows the cut-off price and the electricity prices under which the cap and floor values for 2009 for some RES-E technologies[9] are reached.

The cut-off price is defined here as the one that equals the revenues under the fixed-FIT and the premium options. It is calculated as the difference between the fixed-FIT and the reference-premium. For electricity market prices higher than the cut-off price, investors will obtain more profits under the premium option. For electricity market prices lower than the cut-off price, investors will obtain more profits under the fixed-FIT option.

The electricity prices, under which the cap and floor values are reached, are calculated as follows:

- Electricity price under which the cap value is reached: it is the lowest electricity price that, added to the premium, already reaches the cap value. It is calculated as the difference between the cap value and the reference-premium. For electricity market prices higher than this one, there is no further increase in the total support, being located at the cap value. When the electricity price rises above this price, the premium becomes smaller, representing fewer burdens for consumers. If electricity prices go on rising, they can reach the cap value. In this case the burden[10] for consumer is zero.
- Electricity price under which the floor value is reached: it is the highest electricity price that, added to the premium, reaches the floor value. It is calculated as the difference between the reference-premium and the floor value. For electricity prices lower than this one, there are no changes in the total support level, being always located at the floor value. When the electricity price falls under this price, the premium becomes bigger, representing more burdens for consumers. In the extreme case of electricity prices of zero (the system in Spain does not allow negative electricity prices, as in other countries like Germany), the premium has to equal the floor value. In this case, the burden for end-consumers is maximal.

To illustrate this explanation, let us take the case of wind energy (2009 values). When the electricity prices are higher than 59.42 €/MWh, the cap value is reached. In this case, the profit for investors is higher under the premium option (90.69 €/MWh) than under the fixed-FIT option (78.18 €/MWh). If the electricity prices go on rising up to 90.69 €/MWh, there will be no burden for consumers since the premium will be zero (the electricity price reaches the cap value and therefore no premium is added). When the electricity prices are lower than 44.83 €/MWh, the floor value is reached. In this case, the profit for investors is lower under the premium option (76.1 €/MWh) than under the fixed-FIT option (78.18 €/MWh). If the electricity prices go on sinking up to zero, the premium will be maximal and it will equal the floor value (76.1 €/MWh).

One relevant question, as an RES-E investor, is at which electricity price the profits are higher under the premium option; in other words, where the cut-off price is located. For 2009, this value is located at 46.9 €/MWh for wind energy. That means that, if electricity prices are higher than this value, the investors will make more profits if they choose the premium option. Once the RES-E investors choose the premium or the fixed-FIT option, they have to remain under this option for, at least, one year.

6. Comparison of the dual system in Spain: an analysis of the 2009 values per technology

Figs. 5 and 10 show the total support, cut-off prices and other relevant prices for RES-E technologies. Relevant information regarding the performance of the support system has been extracted from these figures and summarized in Table 6.

Table 6 shows that wind energy is the RES-E that has the relatively best incentive[11] during base load hours (reaching the floor value at the highest electricity price in comparison to the other RES-Es).

Wind energy also has a relatively high floor value (relatively high in comparison to the fixed-FIT), which, in combination with a relatively high cap value, has probably prevented big movement of wind production to the fixed-FIT option during these last years of low electricity prices.

In the biomass sector there has been an important movement back to the fixed-FIT option at the end of 2009. The reason probably

[9] These prices have been calculated for the first payment period, which goes from 15 to 25 years depending on the technology (see Table 2).

[10] Burden for end-consumers is understood here as the difference between the total support for RES-E and the electricity price.

[11] Not in terms of quantity but in relative terms because it reaches the floor value quicker than any other RES-Es.

Table 6
Support system values analysis.

RES-E	Comments on			Support option (2009)
	Premium and fixed-FIT	Cut-off price	Prices reach cap and floor	
Solar thermal	Highest premium and fixed-FIT; reflecting state of market maturity and cost of this technology.	The smallest. Better off under the premium option.	Price that reaches the cap: highest of all technologies. Price that reaches the floor: the smallest. No extra compensation when electricity prices are low.	All capacity under premium option.
Wind			Price that reaches the floor: the highest (44.8 €/MWh)[a]. Floor value relatively high (76.1 €/MWh) in comparison to the fixed FIT (78.2 €/MWh). High support during base load hours.	96% Capacity under premium option.
Geo and marine[b]	Premium is higher than the one for wind energy but the fixed-FIT is smaller.	Better off under the premium option.	No cap and floor.	No facility registered[c].
Hydro-electricity ($10 < P < 50$ MW)	No fixed-FIT. Only premium option. Design appropriate for market mature technologies as this one.		Cap value reached for electricity prices above 62.9 €/MWh. Floor value reached for electricity prices under 42.9 €/MWh.	All under premium (no other option)
Biomass	Array of different biomass sources with different fixed-FIT and premiums.	Cut-off price same for all the subgroups.	Difference between the cap and floor values is small (around 10 €/MWh). The fixed-FIT is a value located between the cap and the floor value. All three values are quite similar[d]. Small incentive to apply for the premium option.	Last years: majority under premium option. 2010: majority under fixed-FIT[e].

Source: Own elaboration.
[a] During the night-time the lowest prices for electricity are reached (normally around 4 and 5 a.m. in Spain), which usually go down to 20 €/MWh (the lowest value in 2009 was zero).
[b] Which are wave, tide, hot rocks, marine current and ocean-thermal.
[c] Until now only research and/or small facilities have been constructed in Spain and no one is selling electricity to the grid.
[d] The difference between the fixed-FIT and the cap value is 7.9 €/MWh for facilities smaller than 2 MW and 4.6 €/MWh for bigger ones.
[e] Data from CNE.

has to be found in the introduction of the cap and floor system, which made the premium option no longer attractive enough for biomass investors. The expected revenues under both options are very similar, even a bit smaller under the premium option if the electricity prices are low. In this situation the stability of the fixed-FIT has been more attractive for the investors.

As stated in Section 4, fixed-FIT creates greater investment security [20]. This lower-risk environment can encourage the participation of smaller and more risk-averse investors [21]. In this sense, fixed-FIT seems adequate to foster the development of RES-E technologies that are not mature from the market point of view or to foster small facilities owned by small investors.

Table 7
Performance criteria per RES-E technology.

RES-E	Deployment indicator	Adequacy to demand pattern	Burden
Solar thermal	Slow development in last decade. Tendency: increasing capacity in the last 2 years[a].	No major incentives to produce during the base load hours (mainly during the night): incentives adequate to demand pattern[b].	High burden reflecting the state of maturity and cost of the technology.
Wind[c]	Quick development. Incentives according to the maturity of the technology.	Due to good support during base load hours: not many incentives to try to locate wind farms accordingly to demand pattern[d].	Burden increases due to relatively high floor value.
Geo and marine	Very small deployment. Non-mature technologies (from the Spanish market point of view)[e]	Premium option designed to encourage adequacy to demand pattern.	
Hydro-electricity ($10 < P < 50$ MW)	Tempered increase.	Considering the versatility of the hydroelectricity to regulate[f], the design of the support system should have taken this issue into account and provide this group with higher cap and lower floor, to encourage production during peak hours.	
Biomass	Slow development.	With high electricity prices, the cap value is reached quickly; therefore not many incentives to produce during the peak hours. Similar comments as for the hydroelectricity category apply here.	

Source: Own elaboration.
[a] Solar thermal electricity increases from 16 GWh in 2008 to 94 GWh in 2009 (www.idae.es).
[b] Since solar thermal energy will naturally produce during the day, this issue should not constitute any problem. In fact, what this design of the support scheme encourages is solar thermal systems with no big storage that should produce during the day and the storage should be dimensioned to last until the evening peak.
[c] Regarding wind offshore, the Spanish Government is considering a bidding system for the establishment of the incentives, based on a public tender for a certain amount of wind capacity. So far, Spain has not installed yet any off-shore wind farm.
[d] To our knowledge, investors make their wind investments in locations depending on calculations based on the yearly equivalent hours and there is no evidence that, so far, the daily wind speed hourly distribution has been taken into account for this purpose.
[e] Array of technologies: geothermal, mature from the technological point of view, and the marine energies, still in a pre-commercial status. Anyhow, from the point of view of the market penetration in Spain, both can be seen as non-mature.
[f] Stop during base load hours and produce during peak hours.

From Table 6 it can be observed that in Spain the fixed-FIT option has not always been encouraged for less mature RES-E technologies. In fact, the design of the geothermal and marine group suggests a direct jump to the market option from a current status of almost no development. Also, solar thermal facilities are encouraged to play in the market arena through the premium option. In this sense, even if these technologies were marginal in 2007 (the year when the royal decree came into force) a direct jump onto the market was suggested, probably because in these sectors big investments with the potential of generating big amounts of electricity were foreseen, especially in the case of solar thermal.

Table 7 shows some performance criteria, taken into account in this paper, for different RES-E technologies.

According to Table 7, the support levels seem to be adequate to foster wind energy and, lately, also, solar thermal; but not enough to foster biomass development or to make new investments in the hydroelectricity sector.

The introduction of the cap and floor system seems to have hindered the market signals in regard to the adequacy of RES-E production to the electricity demand pattern, especially for some RES-E. A reconsideration of these values is advisable.

7. Evaluation of the design criteria of the dual system in Spain

7.1. Comments on the floor value

The floor values seem to be, for some RES-E technologies, relatively high; e.g., wind, minihydro and biomass show floor values very close to the fixed-FIT values. This relatively high floor values lead to, at least, two disadvantages:

- Higher burden for end-consumers in the case of low electricity prices (in comparison to the fixed-premium system).
- Distortions from the point of view of the adequacy of RES-E generation to the electricity demand. These relatively high floor levels create artificial values that partially cancel the electricity market signals. Especially if we consider the current situation where in some countries even negative electricity prices are allowed, like in Germany, and, in such cases, there is a debate about the suitability of keeping all RES-E incentives [33].

7.2. Comments on the fixed-FIT hourly discrimination design

Under the fixed-FIT option the difference between the peak and off-peak tariff is small (amounting from 6.6 to 13.43 €/MWh) in comparison to the changes of the electricity market prices during peak and off-peak hours (average difference from 20 to 30 €/MWh). Therefore, the difference between the peak and off-peak tariff should be higher in order to reflect the real changes in the electricity prices and, what is even more important, to constitute a bigger incentive to produce during the peak hours.

On the other hand, attending to the Royal Decree 661/2007, the peak hours comprise from 12.00 to 22.00 h in summer and from 11.00 to 21.00 h in winter. But the hourly distribution of electricity prices[12] shows that the electricity prices at 10.00, and even at 09.00, are usually as high as at 21.00. Therefore, a revision of the peak and off-peak periods should be considered in order to follow the market behaviour.

7.3. Incentives to adequate RES-E production to demand pattern

Another relevant issue when comparing both systems is the effect of the support scheme on the RES-E production during peak and base load hours. Premium systems directly include the hourly electricity price distribution as part of its total support level, therefore reflecting the prices of peak and off-peak hours (providing that cap and floor values are set in a way that they do not counteract this effect). Fixed-FIT can also do so by differentiating tariff levels for peak and off-peak periods. In this sense, both systems could have a good performance, but, of course, the adequacy to the hourly market signals will be more accurate under the premium option.

7.4. Design criteria of the dual system

After examining the values in the previous sections, there are some remarks regarding the criteria to be taken into consideration for the design of a dual system.

- The fixed-FIT per technology should be a value between the cap and the floor value.
- Small cut-off price, and hence small difference between reference-premium and fixed-FIT, is an indication that this technology will be better off under the premium option.
- Big cut-off price, therefore big difference between reference-premium and fixed-FIT, is an indication that this technology will be better off under the fixed-FIT option.
- Under the premium option, high cap values and, at the same time, low floor values could be a strategy to try to adapt the RES-E production to the electricity demand patterns.
- Mature and well-established technologies that rely on big investments, e.g., hydroelectricity, should only have the option to apply for the premium system.
- Non-mature technologies could have a design where both options are included, but the incentives should be designed in order to encourage their market penetration with a well designed fixed-FIT.
- Size also matters, not only maturity, e.g., a 5 MW_p photovoltaic field is not the same as an integrated photovoltaic house system, at least from the investors' point of view. Small systems, those mean small investors, sometimes even householders, should have the possibility to rely on a well designed fixed-FIT in order to encourage small investments with low risk. In this sense, small house integrated photovoltaic systems and small agricultural or communal biomass facilities should be encouraged through a low risk option as fixed-FIT.
- Photovoltaic and biomass facilities could have the possibility to opt for both schemes (fixed-FIT and premium option), but the fixed-FIT for building integrated photovoltaic systems and small biomass facilities should be different than the one for photovoltaic fields or big biomass installations. So far, in Spain, photovoltaic systems can only apply for the fixed-FIT option. But nowadays photovoltaic energy has notably increased its capacity (from 21 MW in 2004 to 3426 MW at the beginning 2010); therefore, big photovoltaic facilities could also begin its integration into the market system since it is not a marginal technology anymore and it does not rely on small investors.
- Over time, more RES-E technologies will become mature from the market point of view, that means, not only technologically mature but with a wide presence in the national market. There should be a gradual change from the dual system to only a premium option for these technologies that become market mature when the right time comes, but taking into account the exception for small investors, if relevant. This could lead to higher efficiency if the proper values for the premium system are chosen and it will avoid transaction costs caused by the continuous changing of some investors from one option to another and due to the maintenance cost of both systems (these transaction costs make the system more expensive for both sides, administration and investors). In any case, this is a step to be undertaken only for

[12] The hourly distribution of electricity prices can be consulted in www.omel.es.

mature, well-established RES-E technologies. Considering that in 2009 96% of the wind capacity was under the premium option, and considering the high penetration of wind energy in Spain, it seems that the time has come to rethink the duality in the wind energy sector.

In conclusion, the dual system seems to be an interesting option in order to cover the whole range of investors and technologies, but maintaining the dual system simultaneously for all technologies lead to a more expensive system. Therefore, according to technology maturity and the type of investors, the fixed-FIT or premium should be implemented. For transitional cases (e.g., technologies that are under the fixed-FIT option but its evolution shows that they will be better off under the premium system) both options under the dual system can be considered simultaneously in order to facilitate the transitional period, but only for this period.

8. Stability, adequacy to the electricity demand and investors' behaviour

8.1.1. Stability and flexibility

The dual system may be adequate for a transitional period (to encourage investors to go to the market) but with the vision that, at the end of this period (which may vary for each technology), a single system should be defined per technology and range. Mature and well-established technologies based on high investment should only be able to apply for a premium option.

The maintenance of the dual system in the long term is more expensive, and therefore it represents a higher burden for consumers than a well-designed single option system per technology range.

The fight between the government and the RES lobby is a fact that has to be dealt with every time the regulatory framework needs to be updated or changed. But as Del Río [34] also stated, a support system has to provide stability and flexibility at the same time. Stability as guarantee for the investors that their financial plans will be valid over time but also flexibility to adapt to the technological improvements that reduce the cost of RES-E production.

Experience has shown that the specific design and stability of the remuneration scheme is essential for efficient and well-functioning FIT policies, and crucial to maintaining investor confidence [9,28,31].

The Spanish system, so far, has been developed providing stability, guaranteeing that investors could keep their old incentive schemes when new royal decrees came into force, at least for a relatively long period of time. But, at the same time, it has provided flexibility. The flexibility has allowed the Government to adapt the regulatory framework to the new technological status and, also, to rectify failures of previous regulations reducing, therefore, the burden for end-consumers.

Lately, the Spanish Government has undermined the stability in the system. Spain drastically reduced its FIT payments to solar PV projects, and imposed caps on annual installed capacity for this technology, proposing also retroactivity of these measures. The surge in PV projects put unexpected pressure on government coffers, and forced a drastic revision of the policy, which significantly increased the risk perception of Spain's RE policy for investors and manufacturers [35].

8.1.2. Adequacy to the electricity demand pattern

The adequacy of RES-E production to the electricity demand pattern is especially relevant in Spain since wind energy is the most important RES-E (from the generation point of view) and the wind distribution in Spain is characterized by high wind generation at night (during base load hours). In this sense, the electricity demand and the wind generation follow quite different patterns (sometimes even opposite)[13].

If we look for the adequacy of RES-E production to the electricity demand pattern, a premium system appears to be a better option. It makes sense to pay more for the electricity when it is more expensive (more demand) and to pay less when it is less expensive (less demand). But even if the direct burden[14] for consumers is slightly higher?

There is still an open debate concerning direct burden for consumers versus adequacy to the electricity demand pattern. Fixed-FIT seems to guarantee a level of support that, if well designed, could lead to less direct burden for end-consumers. On the other hand, this system does not provide any incentive to adequate the electricity production to the demand pattern. Should a system be designed in a way that could lead to slightly higher direct burden for end-consumers at the beginning but that encourages the adequacy to the electricity demand pattern? In the long-term perspectives, the adequacy to the electricity demand pattern will lead to a faster RES-E market integration and, finally, to a more efficient electricity system.

Direct burdens for end-consumers are, in the end, one part of the electricity cost. But, in order to evaluate the efficiency of the system, the overall electricity system's cost should be taken into account. First, it has been argued by some authors that fixed-FITs distort competitive electricity prices [36]. This distortion arises because the purchase prices offered under fixed-FITs remain fixed over time, regardless of electricity market price trends. This means that even if conventional prices decline dramatically, or any other reasons that may lead to lower overall electricity prices, RE producers will continue to receive the guaranteed prices, leading to higher prices for electricity customers, and thus to an alteration of what the "real" market price would be otherwise [20]. Second, it is also argued that fixed-FITs ignore prevailing electricity demand, offering the same prices regardless of the time of day at which electricity is supplied [22].

On the other hand, a support system that follows the electricity demand pattern will end up with less investment for the security of supply and grid enhancement. Again, direct burdens for consumers are only one part of the overall system cost, where cost for grid reinforcement, security of supply and storage should also be taken into account. According to Klein [19] the premium option shows a higher compatibility with the liberalized electricity markets than fixed-FITs. This involves a better and more efficient assignment of grid costs.

As Hiroux [27] stated, "more market signals are needed to give right incentives for reducing the integration costs[15] but they should not undermine the effectiveness of the support system". They come to the conclusion that the participation in the market, even for intermittent RES-E, like wind, leads to less integration costs.

In summary, fixed-FITs usually lead to less direct cost for RES-E support but, on the other hand, premium systems lead to less integration costs. The overall cost, which should include both costs, should be figured out in order to establish which system leads to less overall costs. This is a field where further research is needed.

Different authors one way or another have already stated that premium system encourages RES-E producers to adapt its generation to the electricity demand pattern. According to the European

[13] Daily wind distribution curves: www.ree.es.

[14] Direct burden is defined here as the one directly derived from the tariff or premium payment.

[15] Integration costs represent additional system-induced costs due to the integration of large-scale RES-E [27].

Commission [20] market-dependent FIT policies, like the premium model, could be employed to help meet peak demand. Premium models create an incentive to supply power in times of high demand, which may provide benefits to both grid operators and society [22].

Policies based on premium systems could also help create a more harmonized electricity market because renewable energy developers are feeding their power into a competitive market place, effectively removing the difference between renewable and conventional electricity. In the long-term, this market integration could be desirable, as RE sources grow in market share, the external costs of conventional generation begin to be factored in, and renewable energy prices continue to move toward parity [20].

8.1.3. Investors' behaviour

The premium system is a support scheme that follows the market price evolution and, therefore, the demand pattern. Knowing this in advance, the premium system should be able to influence the investors' behaviour prior to the decision of making the investment and also when the investment is already made (which means changes in how to manage the facility). Therefore, changes in the investments themselves as well as in the management of the facilities should be a consequence of implementing a premium system.

Some of the positive effects of exposing RES-E producers to market signals can be summarized in the following changes of the investors' behaviour prior to the investment and once the investment is made.

Changes in the management:

- Adaptation of RES-E production to the electricity demand: for the manageable RES-E is a question of responding to the price signals, e.g., for biomass plants.
- Improvement of maintenance planning: to adapt the maintenance services to the base load hours. Market participation implies higher responsiveness to price levels when implementing maintenance planning [27]. This should determine when a plant stops for programmed maintenance.

Prior to investment:

- Optimal sites selection according to daily generation pattern: especially important for RES-E as wind energy, since wind farms could be installed in sites with predominantly high winds during the day. Between two places with the same equivalent hours, the site with more wind during the day (in comparison to the night) should be chosen. Adequate wind site selection should take into account the different temporal values of electricity [27]. So far, investors make their decisions of wind farm location according to the number of equivalent hours but not according to the distribution of these equivalent hours. The adequate price signals, through the integration into the market, should change this investor's behaviour.

All these positive effects will make the system more reliable. Under the premium option, RES-E producers are exposed to the market signals so that they can adopt more efficient behaviour [27].

9. Conclusions

The dual support system in Spain includes all RES-E technologies and can be implemented taking into account the level of market penetration, investment range and maturity of the technology. RES-E technologies close to market maturity, but not yet there, or systems relying on small investors, can benefit from a fixed-FIT and RES-E technologies already well established in the market (e.g., hydro bigger than 10 MW) can only apply for the premium option.

The main advantage of the premium system, in comparison to the fixed-FIT, is that it is a scheme integrated in the electricity market system; therefore the system follows the demand pattern and encourages RES-E production during peak hours.

In order to attract investors to this more market oriented option, the premium was theoretically calculated to provide slightly higher incomes than the fixed-FIT option [4]. One of the advantages of the fixed-FIT is, therefore, that the direct burden for consumers is smaller. Another advantage is also that it provides higher security for investors. On the other hand, premium systems lead to less integration costs.

One disadvantage of the premium option is that it can lead to overcompensations if the electricity prices rise quickly. One way to try to avoid it is to include a cap value. In fact, this happened during 2005 and 2006 in Spain. The electricity prices rose quickly, increasing the incomes of RES-E investors that were under the premium option, especially in the case of wind energy. These unexpected high revenues under the premium option were the main reason that led to the Governmental proposal of setting a cap value [26].

The introduction of a cap and floor system reduces the risk set on RES-E promoters by low market prices and, at the same time, mitigates windfall profits when prices go up. This system is designed to retain the best aspects of fixed-FIT while leaving room to play in the market [4].

The design of a dual system with cap and floor values should take into account not only the premium and fixed-FIT values for each technology, but also the cut-off price and the electricity prices under which the cap and the floor values are reached, since these values will determine the system's performance. The floor value is critical, since it can lead to higher burden for consumers and it can distort the market signals that boost the adequacy of RES-E generation to the electricity demand pattern, especially in periods with low electricity prices.

It is likely that in the next future more RES-E technologies will become cost-effective and there should be a gradual transition to the premium system for these technologies in order to improve the efficiency of the system, since maintaining the dual system in the long term leads to higher costs. This gradual transition implies a transitional period in order to change from fixed-FIT to a premium system; in such cases it could be of interest to maintain simultaneously a dual system[16] so that investors do not feel forced to change to the premium system from one day to another.

Anyhow, the fixed-FIT option should be kept for some cases as for the technologies that have not reached yet a high market penetration, and need to build a market environment. Another case should be ranges of technologies whose investments rely on small investors, e.g., building integrated photovoltaic systems or small biomass systems.

The main objective of a support scheme should be the increase of RES-E. However, the performance of a support scheme should not only be evaluated in terms of the increase of RES-E generation. Since the extra cost of RES-E is paid by the end-consumers, burden for consumers is also an issue. It has to be highlighted that the maintenance of the dual system in the long term is more expensive, and therefore, it represents a higher burden for consumers than a well-designed single option system per technology.

The adequacy of RES-E production to the electricity demand pattern has also become an issue of greater importance since RES-E production has increased its contribution and it is not marginal any more. This adequacy will lead to a higher RES-E penetration

[16] Understanding simultaneous dual system as both options, fixed-FIT and premium, available at the same time.

at a lower integration cost. In this sense, a support scheme has to be designed in order to encourage RES-E generators to produce accordingly to the electricity demand pattern. A premium system has more possibilities to succeed in this purpose.

In conclusion, a dual system seems to be adequate to offer a premium option to mature technologies and to big facilities and a fixed-FIT option to small investments or non-mature technologies. In any case, this dual option should not offer both options at the same time except for transitional periods, since in the long term this will lead to higher cost for both, society and administration.

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